THE EFFECT OF THE 1857 FORT TEJON EARTHQUAKE ON TREES NEAR WRIGHTWOOD, CALIFORNIA

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INTRODUCTION

Trees may suffer damage during major earthquakes due to shaking and faulting of the ground beneath them. External effects, such as topping, root and limb damage, and scars may result in a temporary reduction in the width of their annual growth rings. Tilting and changes in environmental factors, such as light, space and water availability may initiate asymmetric growth. Dendrochronologic techniques enable dating of such growth anomalies, and hence earthquakes.

To determine whether or not trees contain useful records of pre-historic earthquakes in southern California, we cored five trees along the 1857 break of the San Andreas fault near Wrightwood, California. Sampling was neither systematic nor exhaustive, since we restricted sampling to conifers recognized during the course of earlier geologic studies along the fault trace. We extracted sample cores with both power and manual increment borers. Dates were determined by counting annual rings. The width of each was measured and plotted against its growth year. We examined all significant departures from normal growth trends and tried to interpret them in light of the 1857 earthquake and other known environmental factors.

THE TREES

A healthy Jeffrey Pine, the <u>Sidehill Bench Tree</u>, is growing astride the San Andreas fault on a fault-related sidehill bench northwest of Big Pines (Figure 1). A core taken from the northwest side of the tree reveals a scar involving the growth rings of the years 1855-57; the 1856 and 1857 rings are missing altogether (Figure 2, WRW 35). In other cores a growth minimum is evident in 1857 (Figure 2 WRW 36).

The ring-ratio plot (SE/NW), calculated by dividing the ring widths on the southeast side of the Sidehill Bench Tree by correlative ring widths on the northwest side, displays two conspicuous anomalies (Figure 3). The ring ratios are close to 1.0 except during the ten years following 1857 and during the twenty years starting about 1960. The first anomaly we attribute to damage to the northwest side of the tree during the 1857 earthquake. The second anomaly is probably due to an increased growth rate on the southeast side of the tree resulting from the removal of a nearby competitor, the Stump Tree.

A few meters southeast of the Sidehill Bench Tree, and a meter northwest of the fault zone, lies the stump of a White Fir dubbed the <u>Stump Tree</u>. A part of the tree's crown, discovered nearby, suggests that the tree was never topped and originally measured a little more than 23 m in height. The Stump Tree shows a dramatic reduction in ring width beginning 101 years before it was felled (Figure 4). Recovery from the trauma took about 25 years. According to Ranger S. R. Carbaugh (pers. comm.), the Stump Tree was probably killed during a "sanitation salvage" logging program in about 1957-58. If the ring record is plotted so that the last ring dates from 1958, the slowdown begins in 1857. Killing of the Stump Tree in 1958 is consistent with the sudden burst in growth on the southeast side of the Sidehill Bench Tree beginning about 1960 (see Figure 3). We

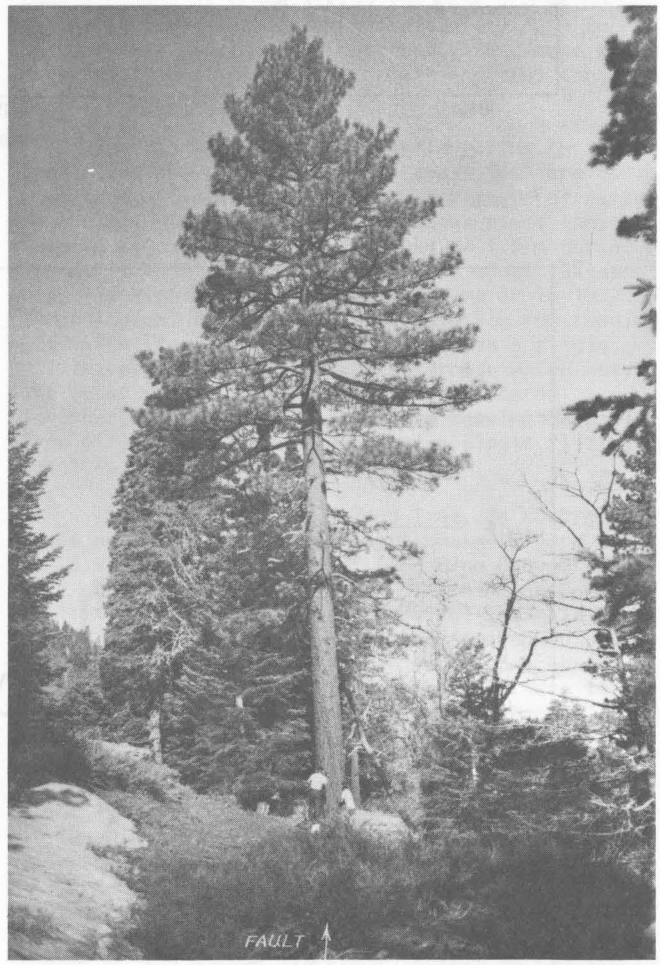

Figure 1. Sidehill Bench Tree. Stump Tree hidden by brush in foreground.

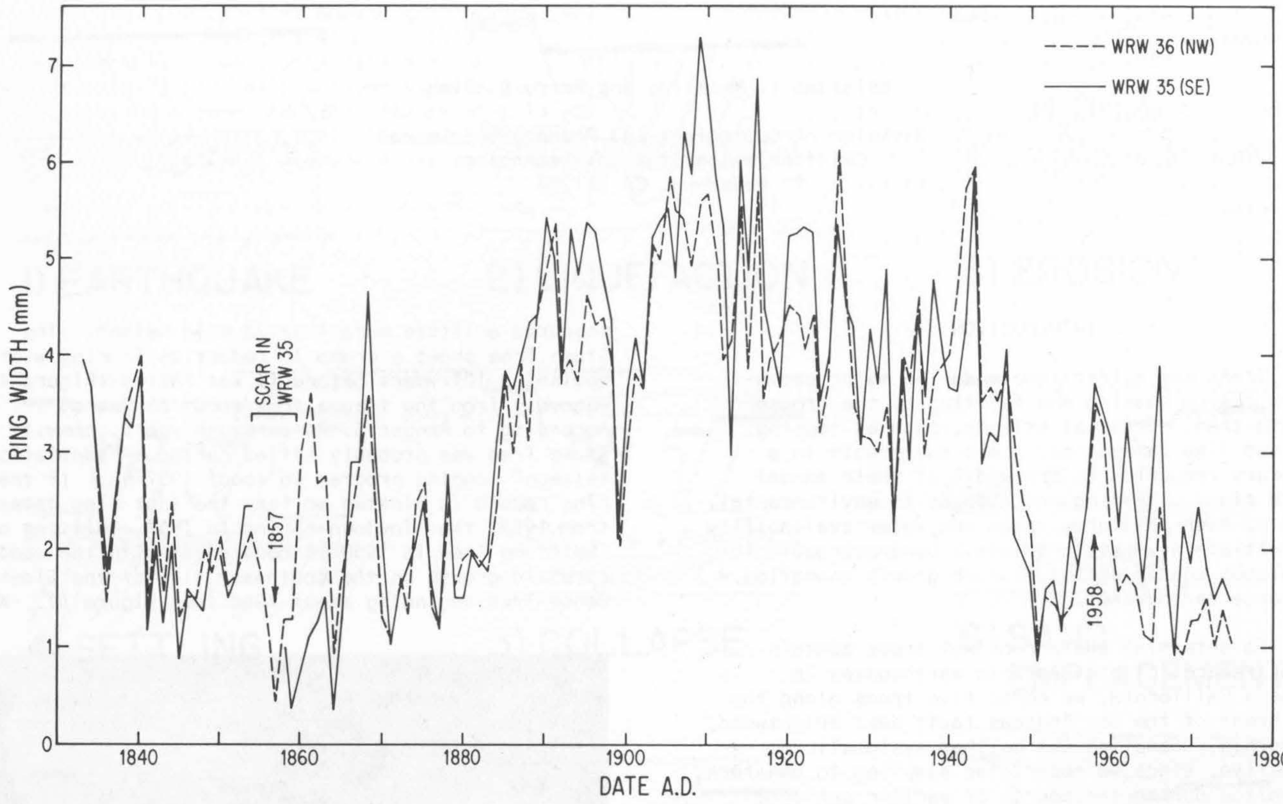

Figure 2. Sidehill Bench Tree ring width.

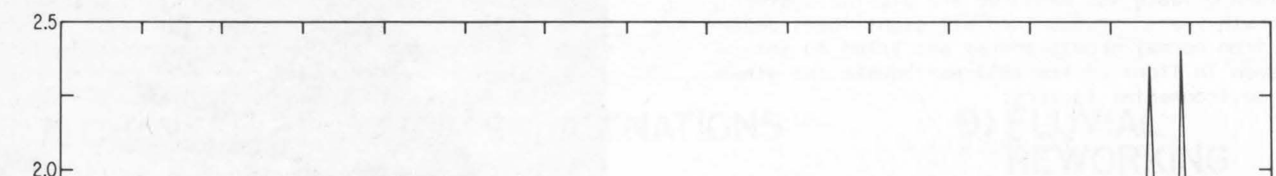

Figure 3. Sidehill Bench Tree ring ratio.

were not successful in precisely dating the Stump Tree records by correlation with the Sidehill Bench Tree; but, in light of the evidence presented herein, it seems likely that the Stump Tree suffered root and/or limb damage during the 1857 earthquake.

In Wrightwood, a pair of Jeffrey Pines are located on a low, linear mound southeast of the engineered levee of Heath Creek (Figure 5). They lean away from each other and show a pronounced asymmetry of both trunk and crown. Bends occur in the trunks of both the Leaning Tree and the Leaning Companion Tree. The lower 7.5 to 12 m of the Leaning Tree tilts 12° to the northwest; above 12 m the trunk tilts considerably less. The Leaning Companion Tree tilts 13° to the southeast below an abrupt bend in the trunk at about 3.5 m; above this bend the trunk is nearly vertical. These effects could be the result of mutual competition for space and light, but, because both trees are rooted in the fault zone, we suspected that the tilts might also be related to the 1857 earthquake. Eight cores were taken from the Leaning Tree and one from the Leaning Companion.

Different core records within the Leaning Tree correlated well with each other, although attempts to correlate with ring records from other trees were unsuccessful. The oldest ring penetrated by cores of the Leaning Tree formed in 1846; the tree was probably about 1.5 m tall in the late 1830's. One core on the northwest side shows a slowdown and recovery anomaly beginning in 1856 (Figure 7, WRW 18). The ring-ratio plot (SE/NW) shows a 20-year positive anomaly beginning in 1856, followed by a long sustained negative anomaly (Figure 9).

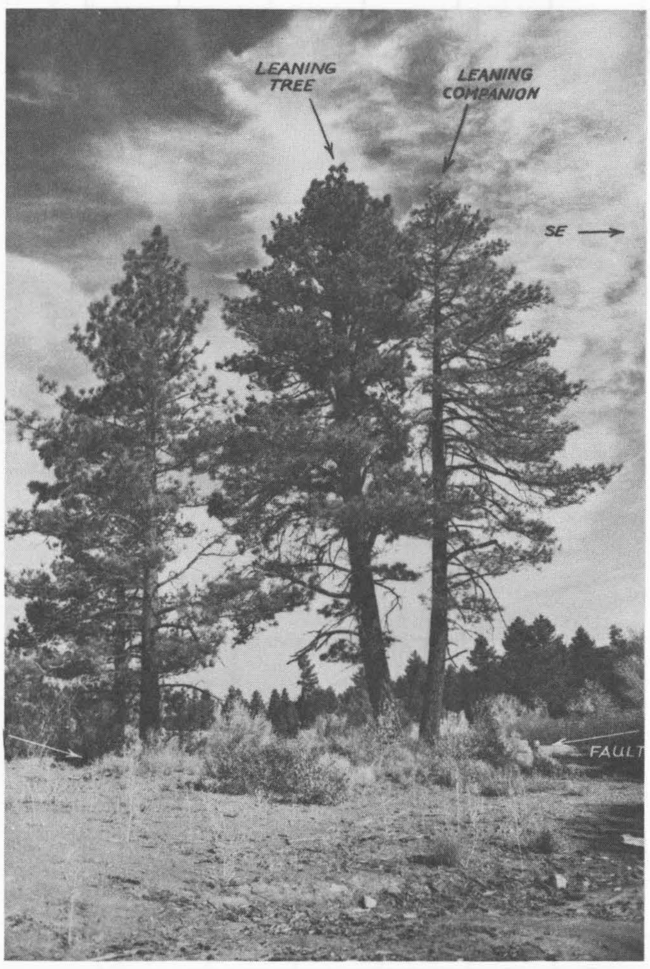

Figure 5. Leaning Tree and Leaning Companion Tree.

Morphological features and ring data for both the Leaning Tree and the Leaning Companion Tree are consistent with a single tilting event in 1857. The Leaning Tree was about 20 years old, 10 m high and about 15 cm in diameter at the time of the earthquake. We propose that the 20-year ring-ratio anomaly reflects trauma caused by root or limb damage suffered during fault slippage underfoot in 1857. After recovery, the tree's shifted center of gravity led to increased growth on the northwest side relative to the southeast side. The competitive influence of the Leaning Companion Tree heightened the tendency. The asymmetry of the Leaning Tree actually began in 1856. According to available rain records, 1856 was a moderately dry year, but response to water shortage should not have been asymmetric. Although it is tempting to interpret this early onset of trauma as evidence of root damage caused by creep during the year preceding the earthquake, there are not sufficient data to warrant this conclusion. Pest and wind damage might have resulted in asymmetric growth and thus cannot be ruled out.

The Leaning Companion Tree is rotten in the center and the rings older than about 1869 are not preserved. It is not clear how many years of early record are missing, but our estimates place the Leaning Companion Tree at a height of 1.5 m during the early 1840's. Thus the tree was about 15 years old, 4 m high and about 10 cm in diameter in 1857. Morphological features and ring data for the Leaning Companion Tree are also consistent with a single tilting event in the mid-1800's through which only the outer rings survived intact. Considered together, the Leaning Tree and the Leaning Companion Tree offer compelling evidence of a single tilting event in 1856-57.

The Lone Pine Canyon Road Tree, in contrast, shows no effect of the 1857 earthquake (Figure 8). It is situated just south of Lone Pine Canyon Road, west of the saddle at the head of Lone Pine Canyon. It lies about six meters southwest of the main trace of the San Andreas fault, and was once topped about 15 m from its base, where three large branches have subsequently grown. The tree appears to have lost its entire crown at the time of the topping.

The Lone Pine Canyon Road Tree was about 1.5 m high in 1749. A slight southwestward tilt of the lower 1.5 m of the trunk suggests a tilting event in the mid-1700's. A core taken on the northeast side shows a dramatic slowdown beginning in 1834 (Figure 6). The core shows no obvious effect of the 1857 earthquake. Either the Lone Pine Canyon Road Tree was not seriously damaged during the 1857 earthquake, or the damage sustained in 1834 so limited the tree's growth that the effect of later damage cannot be recognized. We favor the second hypothesis, and cite as evidence the anomalously long 55-year recovery period that follows the topping event (see Figure 6). No large or moderate earthquakes are recorded for this region in 1834, so we conclude that the tree was probably topped by lightning or wind in 1834.

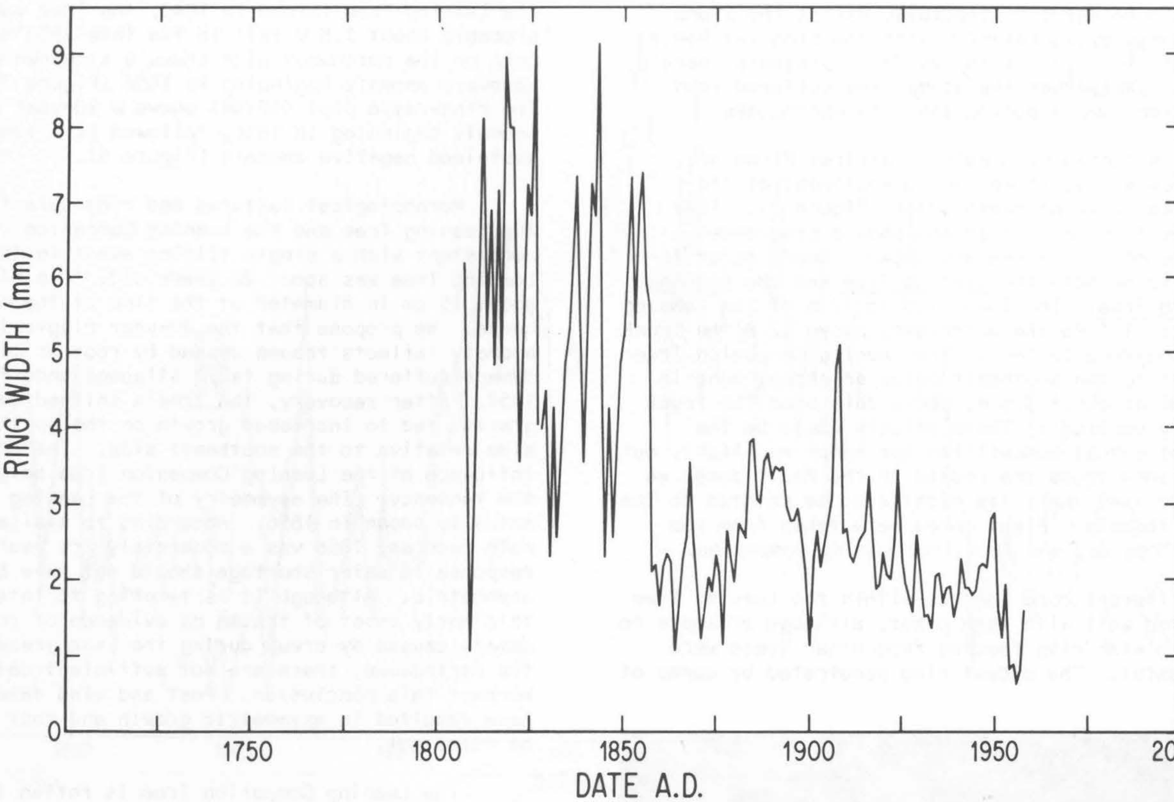

Figure 4. Stump Tree ring width.

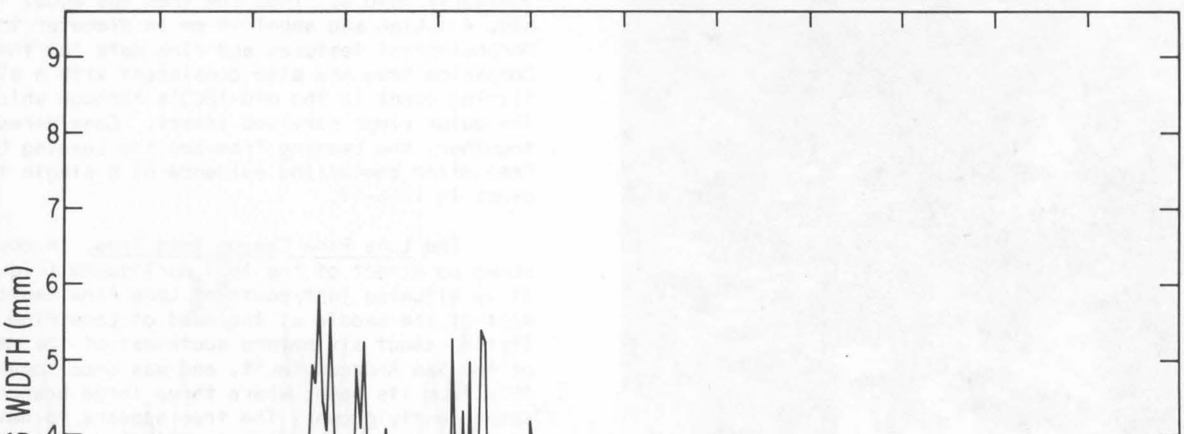

Figure 6. Lone Pine Canyon Road Tree ring width.

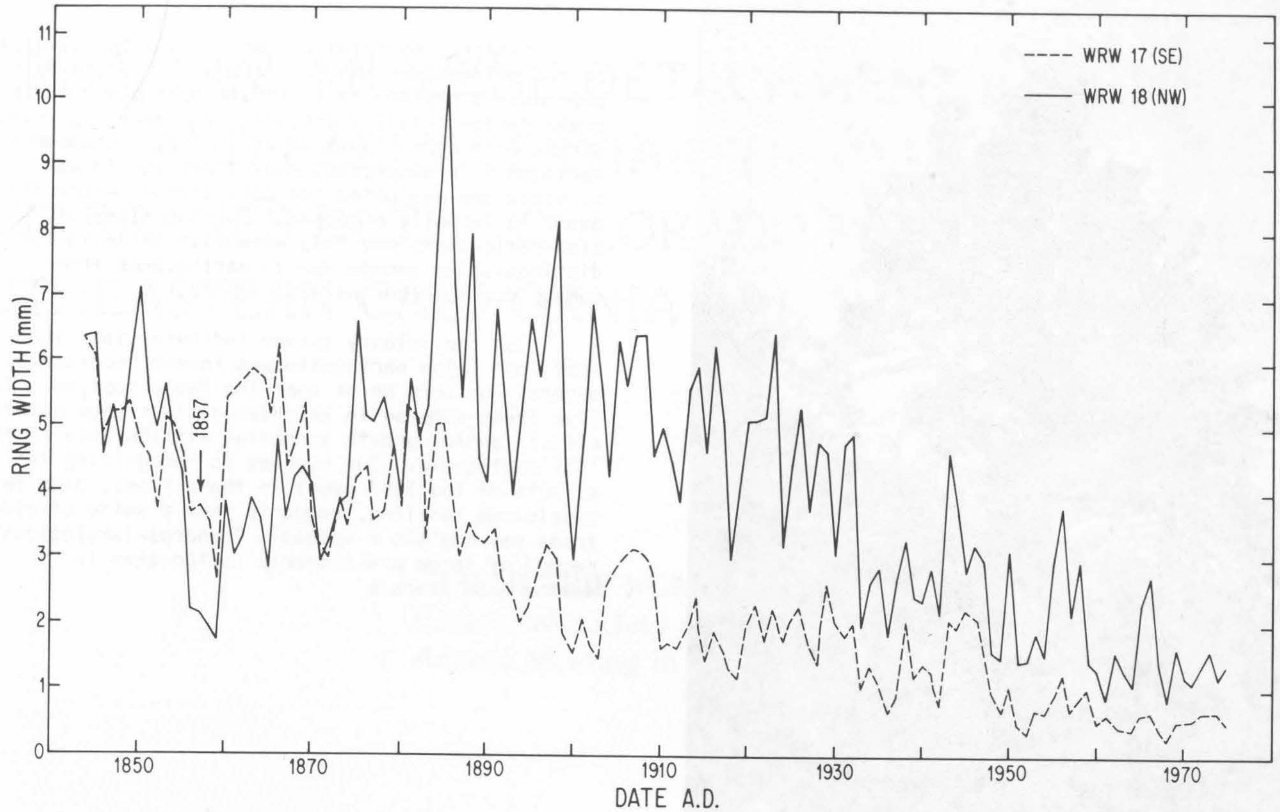

Figure 7. Leaning Tree ring width.

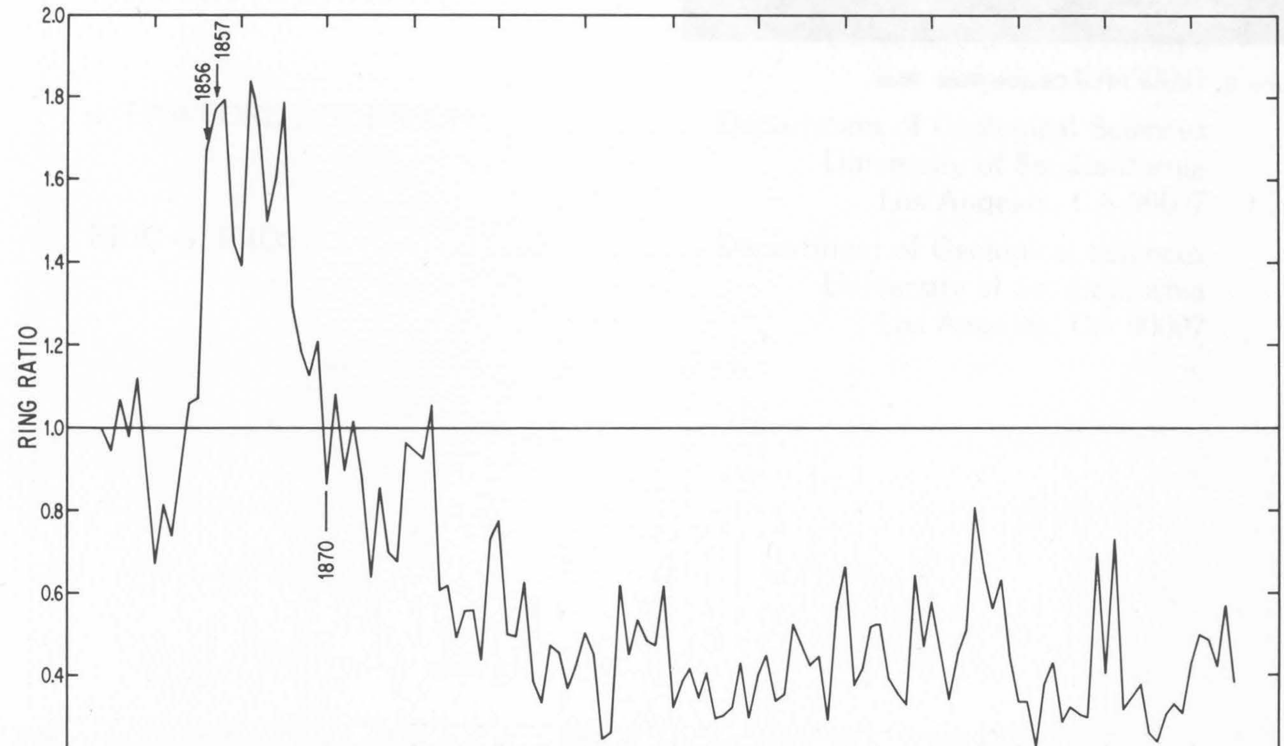

Figure 9. Leaning Tree ring ratio.

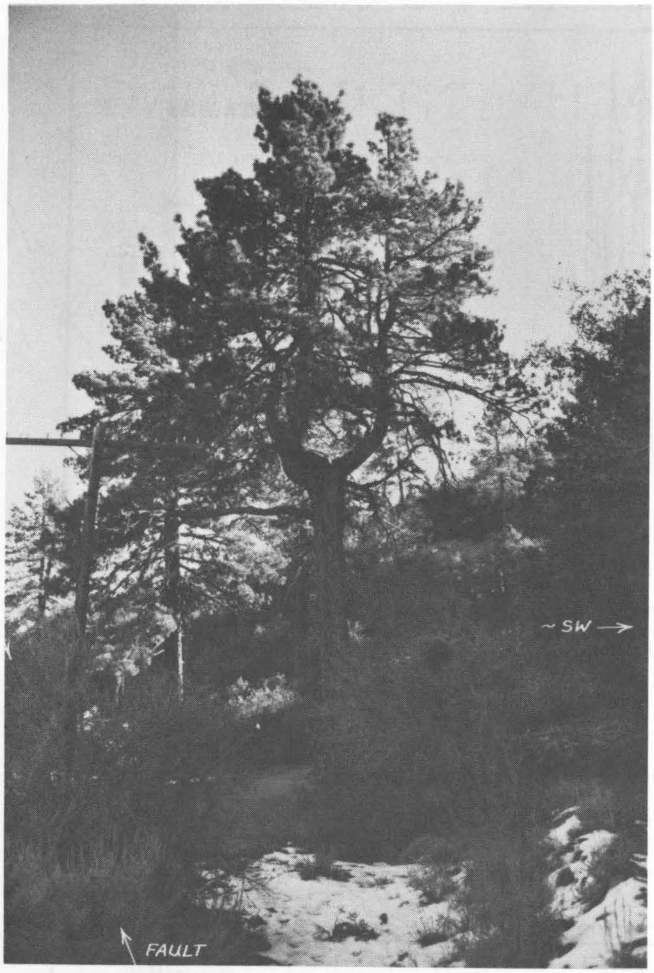

Figure 8. Lone Pine Canyon Road Tree.

CONCLUSION

Clearly, no seismic event should be postulated on the evidence of one tree alone. It would be an embarassing mistake to attribute to a great earthquake damage actually produced by a mere lightning strike or a strong gust of wind! If an undocumented earthquake is suspected, many trees should be examined and evaluated for consistency before the event is formally proposed. Further study of ring-ratio plots may help establish criteria for distinguishing damage due to earthquakes from damage due to other natural agents.

Our preliminary survey indicates that the 1857 Fort Tejon earthquake was indeed recorded by several conifers on or near the fault rupture. Of five trees sampled in Wrightwood, four show damage effects and/or growth anomalies attributable to the 1857 earthquake. Our success in recognizing the effects of the 1857 event in these trees, despite capricious sampling, suggests that a suite of older trees may contain a valuable "dendroseismological" record of large pre-historic earthquakes in southern California.